

3.—FORAMINIFERAL INVESTIGATIONS IN THE PERTH BASIN, WESTERN AUSTRALIA.

by

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ABSTRACT.

Micro-faunal examination of five Perth artesian bores show the presence of Eocene and Cretaceous beneath a thin cover of Quaternary. In King's Park Bores 1 and 2, Recent-Pleistocene foraminifera occur down to 84 feet, Eocene forms from 84-780 feet, and probably Cretaceous varieties from 1,535-1,770 feet. In the Langley Park bore, Eocene foraminifera occur from 208-975 feet. An easterly dip is possible. The Belmont Park bore yielded few foraminifera but Eocene forms were found at 530 feet and sporadically between 840-900 feet. The Power House bore and the upper part of the Mt. Lyell (Bassendean) bore were unfossiliferous. Finer subdivision of the Eocene was inconclusive.

INTRODUCTION.

Comparatively little is known or published concerning the sedimentary layers which compose the coastal plain in the vicinity of Perth. The small angle of dip of these beds, their lenticular nature, the absence of outcrops, and the ubiquitous cover of recent sands and alluvium have made the discovery of their nature and structural relations extremely difficult. All that can be concluded, after allowing for the paucity of evidence, is that the beds beneath the Coastal Plain in the vicinity of Perth (the "Perth Basin"), are composed, to a depth of over 2,000 feet, of calcareous shales, mudstones, sandstones, and sands, overlain by Recent sands and in part, by Pleistocene limestones. Upper Eocene fossils have been found in some of these beds, generally at depths less than 800 feet. Below them, and at varying depths, between 1,550 feet to 1,800 feet, Cretaceous fossils have been found (Clarke, Prider and Teichert, 1944).

The structure of the beds beneath the Swan Coastal Plain must be intimately connected with the nature and history of the Darling Scarp. The generally accepted view as to the origin of the scarp is that it is a true fault scarp, post-Miocene in age (Saint-Smith, 1912, p. 70; Jutson, 1912, p. 149, and 1934, p. 86; Woolnough, 1918).

Recently it has been suggested (Prider, 1941, 1948) that the Darling Scarp is an erosion feature due to differential erosion of a monoclinical fold rather than a fault scarp, the observed characteristics of the scarp being explicable by the differential erosion of the hard Pre-Cambrian rocks to the east and the softer, later rocks to the west of the scarp. The down-warping he considers to have been in operation since late Pre-Cambrian times.

This suggests that the post-Proterozoic rocks of the Coastal Plain may descend to great depths, containing Mesozoic and older sediments beneath the already recognised Tertiaries. Deep drilling, using foraminiferal evidence and geophysical methods which would indicate the depth of the Pre-Cambrian bed rocks, is needed to test the truth of this hypothesis.

The Perth Basin has proved a useful artesian reservoir and the bore logs furnish what little is known of the stratigraphy and structure. This data is not altogether satisfactory because:—

- (i) Comparatively few bores have been sunk, and few of these are deeper than 2,000 feet.
- (ii) Very few of them have been sampled, and most of these were done rather haphazardly. Also many of the available samples are from percussion bores and are thus only mud samples, not actual cores.
- (iii) The drillers' logs are rarely satisfactory from the geologists' point of view; indeed, they are often more confusing than helpful.
- (iv) Little work has been done on the fossil content of the bores.
- (v) A large part of the area yields bore-samples which are completely unfossiliferous.

To date only two papers have been published concerning information yielded by bores. The first of these was an article by F. G. Forman (1933). This was the result of a comprehensive survey of most of the bores that had been put down in the metropolitan area prior to 1932, in an attempt at correlation based on the nature of the ground waters, dissolved salts, depths of the principal water horizons, static heads, temperatures of the waters, and to a certain extent, on lithology. The conclusion reached was that the information available was insufficient and of too doubtful a character to be used to produce accurate structural contour maps, but he succeeded in correlating the principal aquifers.

The second paper by Parr (1938) dealt with the description of the foraminifera found in samples from two adjacent bores—King's Park Nos. 1 and 2. He recorded nearly 70 species of foraminifera, some ostracoda, bryozoa, and sponge remains. He concluded that the age of the beds from which the samples came, between approximately 80 and 780 feet, were Upper Eocene.* The frequency chart compiled by Parr indicated that certain species could be used as index species and that particular assemblages characterised certain parts of the bore sections.

In an appendix to Parr's paper, it was noted that Lower Cretaceous foraminifera were also identified by Crespin from two other bores, the Leederville and Zoological Garden's bores, in samples from between 1,660 and 1,750 feet approximately.

Parr's results suggested that at least a rough zonal division of the upper beds was possible and prompted the examination by the writer of samples from five bores put down for artesian water. These samples had been stored in the Geology Department of the University of Western Australia for some years. The bores were percussion type, casing being used and kept within some 30 feet of the bottom. A certain amount of contamination was inevitable, but the range of contamination probably would not exceed 50 feet. They had been sampled with a fair degree of precision at approximately 20–30 feet intervals, and at noticeable changes in lithology. Many samples were scrapings from the bit as distinct from the less desirable bailer samples.

* Dr. R. W. Fairbridge informs the writer that he is proposing the name *King's Park Shale* for this sequence, while the underlying unfossiliferous formation is to be named the *Leederville Sandstone*. This in turn rests on the fossiliferous, Lower Cretaceous shales, for which he proposes the name *South Perth Shale*.

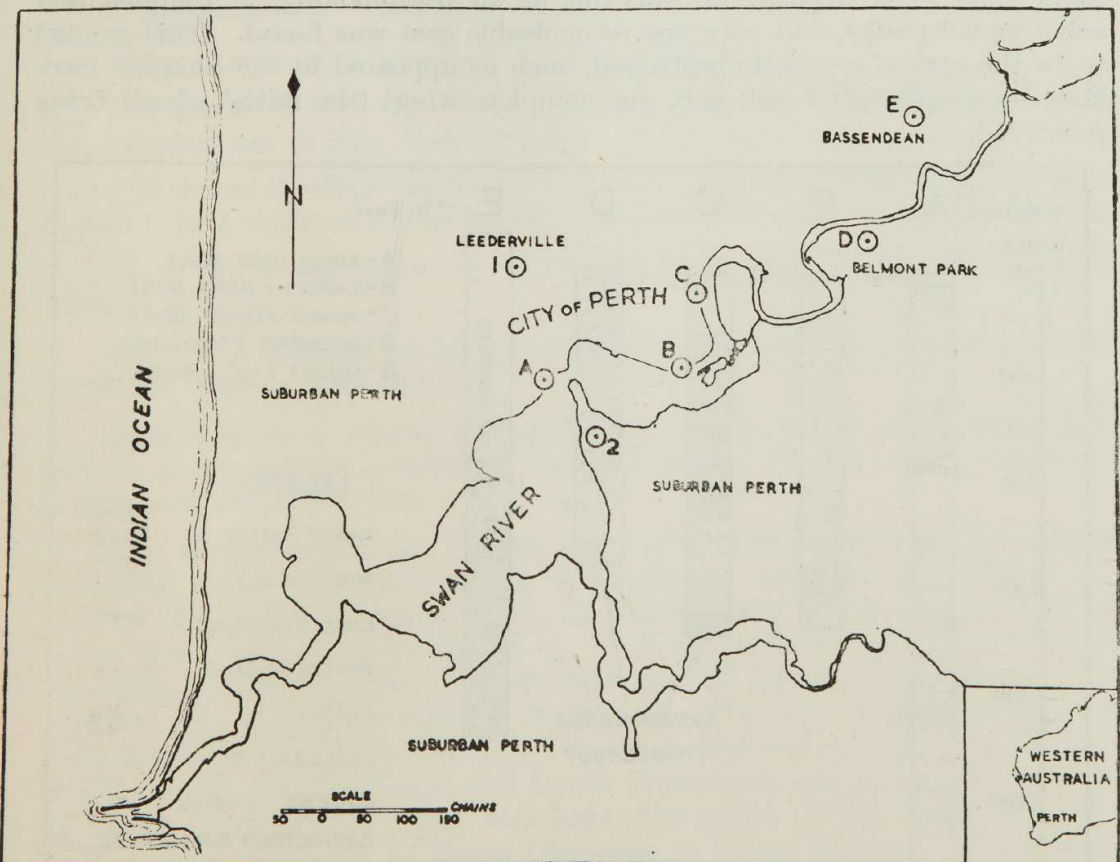
DESCRIPTION OF THE BORES.

The bores from which the samples came were :—

- (i) The King's Park Bores, Nos. 1 and 2, put down near the Swan Brewery, Mount's Bay Road (see Locality Map, text fig. 1). Bore No. 1 at a depth of about 1,350 feet encountered a granite boulder and was abandoned. Bore No. 2, sunk a few feet away, penetrated to a depth of 2,406 feet.
- (ii) The Langley Park Bore—depth 1,238 feet, situated a few hundred yards west of the Causeway, approximately two and one-quarter miles east of the King's Park Bore.
- (iii) The Power House Bore—depth 1,300 feet, near the main Power House, one and one-eighth miles N.N.E. of the Langley Park Bore.
- (iv) The Belmont Park Bore—depth 1,128 feet, at the Belmont Park Race Course, two and three-quarter miles E.N.E. of the Power House Bore.
- (v) The Mt. Lyell Bore—depth 1,900 feet, at the production plant of Cuming, Smith and Mt. Lyell Fertiliser Company, Bassendean, about two miles N.N.E. of the Belmont Park Bore.

The bores, therefore, give a section approximately seven miles long, on a general line trending S.W.—N.E.

Text figure 2 gives the diagrammatic logs of the bores with the lithologic divisions. It can be seen that correlation based on lithologic grounds would be most uncertain.



Text fig. 1.

Locality map of the Bores: A—King's Park Nos. 1 and 2. B—Langley Park. C—Power House. D—Belmont Park. E—Mount Lyell. Also mentioned in the text were: 1—Leederville and 2—Zoological Gardens Bores.

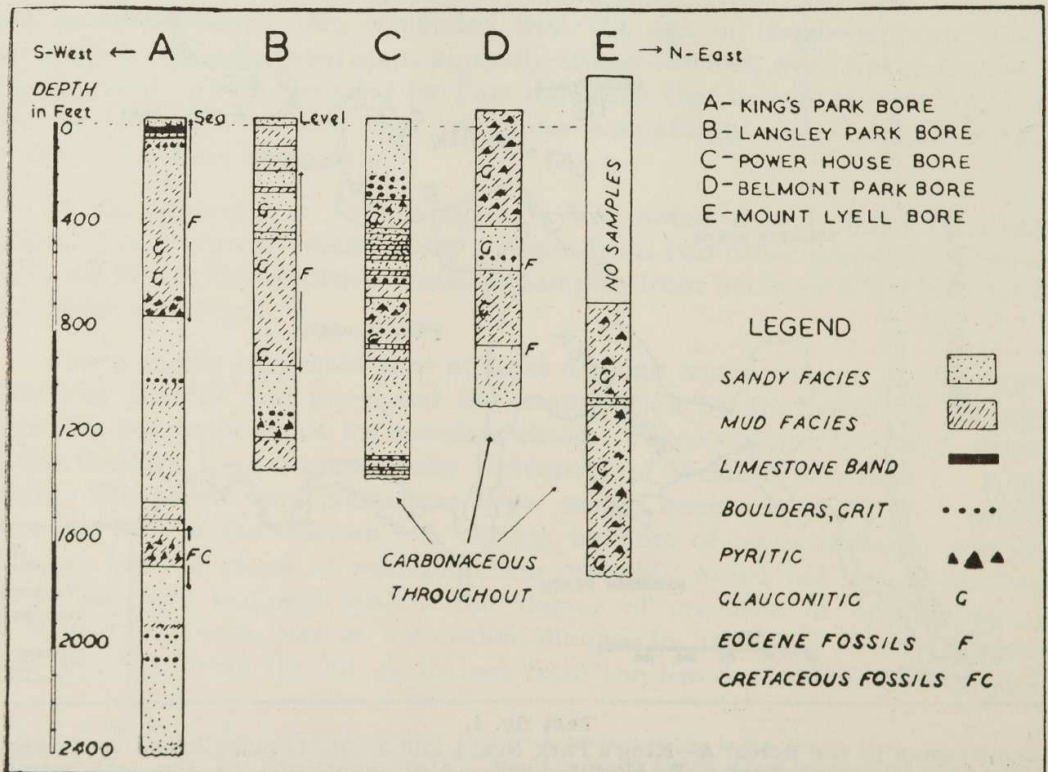
All five bores show a somewhat similar lithology. They pass through a surface sheet of recent sands and alluvium, then through a series of sands, sandstones, sandy shales, mudstones, in irregular succession, with coarse grits and gravel deposits (some representing the water horizons) at irregular intervals. The King's Park Bore passed through thin layers of limestone at the surface and at 84 feet.

Foraminifera were found in three only of the bores—the King's Park, the Langley Park, and the Belmont Park Bores. The Power House and Mt. Lyell Bores were unfossiliferous.

The fossiliferous material was a light grey fine shale or mudstone, at times rather sandy. Only when bit samples showed the unpulverised laminated shale fragments was it possible to decide definitely whether the material was shale or mudstone. It was noted in the Langley Park Bore that with an increase in sand content there was a corresponding diminution in the number of foraminifera. The shales of the Langley Park and Belmont Park Bores, particularly in the latter, were more sandy than those of the King's Park Bore.

This finer fossiliferous shale did not appear in either the Power House or Mt. Lyell Bores. Instead the shale or mudstone was very sandy, angular quartz grains predominating, was pyritic with sometimes a high proportion of glauconite, and generally contained a large amount of woody charcoal-like material. This sandy mudstone appeared in the non-fossiliferous portions of the other three bores.

Glauconite occurred in all the bores, but it was probably derived from some other older deposit. It was not at all fresh-looking, in rounded and sub-rounded grains, and only one recognisable cast was found. This seemed to be the cast of a minute gastropod, such as appeared in the Langley Park Bore—a simple spiral coil, only one complete whorl (the initial whorl) being preserved.



Text fig. 2.

Diagrammatic presentation of the lithology of the five bores examined.

DESCRIPTION OF THE FAUNA.

Foraminifera were found in the King's Park Bore between 0–84 feet (Recent-Pleistocene) and 84–780 feet (Eocene) and 1,535–1,770 feet (Cretaceous); in the Langley Park Bore between 10–90 feet (Pleistocene), and 208–975 feet (Eocene); and in the Belmont Park Bore at 530 feet, 840–900 feet, the foraminifera in this bore being very rare and poorly preserved.

Standard methods of procedure were used to extract the fossiliferous content of the samples. Flotation methods using a heavy liquid of bromoform and alcohol, specific gravity 2, gave excellent concentrates except for a few unsuitable samples.

The Eocene foraminiferal fauna was especially selected for study, both on account of its relative abundance and its unique position in the Australian sequence.

Fossils occurring in the residues were:—

- (a) Foraminifera (most abundant).
- (b) Sponge spicules (abundant).
- (c) Ostracods—rare.
- (d) Bryozoa—rare.
- (e) Minute pelecypods and gastropods—rare.
- (f) Echinoid spines—rare.
- (g) Minute corals—extremely rare.
- (h) Radiolaria—extremely rare.

The sponges are represented by several species:—

The genus *Geodia*—as white, reniform, spherical spicules abundant in the Langley and King's Park samples.

The genus *Geodites*—as white, annulated spicules, more restricted than *Geodia*. It is confined to the section below 375 feet in the King's Park Bore.

There are several other types, mainly represented by tetractinellid and lithistid spicules.

About ten different varieties of ostracods were met with including several species of *Cythere* and *Bairdia*.

Several types of minute gastropods were found, and in the Langley Park Bore a well preserved pelecypod, which persisted through many samples to a depth of about 600 feet.

The simple corals are minute and rarely well-preserved. The largest measured nearly three millimetres in length and one millimetre largest diameter. Through the agency of Dr. D. Carroll, then of the Geology Department, these were identified by Dr. J. W. Wells, of Ohio State University, as belonging to two species—*Trematrochus* sp. aff. *lateroplenus* Dennant, the other a new species, probably? *Oculina* sp.. *Trematrochus lateroplenus* has been found previously in Southern Victoria in Balcombian strata at Shelford, Muddy Creek, Fishing Point, and Lower Moorabool, and in Janjukian strata at Spring Creek, Cape Otway, and Lake Alexandria (Wells, 1942). It has a known range, therefore, of Upper Oligocene to Lower Miocene. These corals were found in samples at 300–320 feet and from 400–440 feet in the Langley Park Bore.

Radiolaria occurred in a few samples in the three Bores.

Echinoid spines belonging to a single type were found in many samples from the Langley Park Bore.

Except in a few instances where the spicules of *Geodia* sp. outnumbered them, the foraminifera were by far the most abundant fossils found. They were mainly small, poorly preserved, and more or less typical of moderately deep water. Only six species approached or exceeded a millimetre in greatest dimension—notably :—

Cyclammina incisa (Stache).
Globulina rotundata (Bornemann).
Guttulina irregularis (D'Orb).
Lenticulina sp. II.
Nodosaria sp. aff. *raphanistrum* (Linne).
N. affinus (D'Orb).

Over ninety species of foraminifera were found in material from the three bores. Many of these are so rare or badly preserved that they are not recorded here. Those identified are :—

<i>Alabamina obtusa</i> var. <i>westraliensis</i> Parr.	<i>Hopkinsina</i> sp. nov.
<i>Anomalina</i> sp. I.	<i>Lagena acuticosta</i> Reuss.
<i>A.</i> sp. II.	<i>L. luciae</i> Parr.
<i>A. perthensis</i> Parr.	<i>L. orbignyana</i> (Sequenza).
<i>A. pseudoconvexis</i> Parr.	<i>L. perthensis</i> Parr.
<i>A. westraliensis</i> Parr.	<i>L. squamosa</i> (Montagu).
<i>Angulogerina subangularis</i> Parr.	<i>L. terrilli</i> Parr.
<i>Bathysiphon</i> sp.	<i>L.</i> sp. III.
<i>Boliviniopsis crespinae</i> Parr.	<i>Lenticulina rotulata</i> (Lam).
<i>Buliminella westraliensis</i> Parr.	<i>L.</i> sp. I.
<i>Cassidulina</i> sp.	<i>L.</i> sp. II.
<i>Ceratobulimina westraliensis</i> Parr.	<i>L.</i> sp. III.
<i>Cibicides lobatulus</i> (Walker & Jacob).	<i>L.</i> sp. IV.
<i>C. umbonifer</i> Parr.	<i>L.</i> sp. V.
<i>C.</i> sp. aff. <i>victoriensis</i> Chapman, Parr & Collins.	<i>Marginulina</i> sp. I.
<i>Cornuspira involvens</i> (Reuss).	<i>M. gladius</i> Philippi.
<i>Cyclammina incisa</i> (Stache).	<i>M. subbullata</i> Hantken.
<i>Dentalina</i> sp. I.	<i>Nodosaria affinus</i> (D'Orbigny).
<i>D.</i> sp. II.	<i>N. ovicula</i> .
<i>D.</i> sp. III.	<i>N. radricula</i> (Linné).
<i>D. colei</i> Cushman & Dusenbury.	<i>N.</i> sp. aff. <i>raphanistrum</i> .
<i>Discorbis</i> sp. I.	<i>N.</i> sp. IV.
<i>D. assulatus</i> Cushman.	<i>Nonion novozealandicus</i> Cushman.
<i>Dorothea</i> sp.	<i>Pattelina advena</i> Cushman.
<i>Elphidium excavatum</i> (Terquem).	<i>Pseudoglandulina clarkei</i> Parr.
<i>E.</i> sp. aff. <i>macellum</i> (Fichtel & Moll)	<i>Quinqueloculina venusta</i> Karrer.
<i>Epistomina elegans</i> (D'Orb).	<i>Q. vulgaris</i> D'Orb.
<i>Eponides exiguus</i> .	<i>Q. seminulum</i> (Linné).
<i>Fronidularia australis</i> Herron-Allen and Earland.	<i>Q.</i> sp. IV.
<i>F.</i> sp. aff. <i>parkeri</i> Reuss.	<i>Robulus warmani</i> (Barbat & Von Estorff).
<i>Globigerina orbiformis</i> (Cole).	<i>R.</i> sp. II.
<i>G. mexicana</i> (Cushman).	<i>R.</i> sp. III.
<i>Globorotalia</i> sp. I.	<i>Robertina</i> sp. I.
<i>G.</i> sp. II.	<i>R.</i> sp. aff. <i>convulata</i> (Will).
<i>G. chapmani</i> Parr.	<i>Strebleus beccarii</i> (Linné).
<i>Globulina</i> sp. I.	<i>Spiroplectamina</i> sp.
<i>G. gibba</i> D'Orb.	<i>Sigmomorphina</i> sp.
<i>G. rotundata</i> (Bornemann).	<i>Spirillina</i> sp. I.
<i>Gumbelina venezuelana</i> (Nuttal).	<i>S.</i> sp. II.
<i>Guttulina irregularis</i> (D'Orb).	<i>Vaginulina</i> sp. I.
<i>Gyroidina soldanii</i> (D'Orb).	<i>V.</i> <i>subplumoides</i> Parr.
<i>G. soldanii</i> var. <i>octocamerata</i> Cushman & G. D. Hanna.	<i>Vaginulinopsis</i> sp.
<i>Heronallenia pusilla</i> Parr.	<i>Valvulineria sculpturata</i> Cushman.
	K_2 genus novus ?
	AL_2 <i>Anomalina</i> sp.

The faunal assemblage as a whole is unlike that of any other region in Australia.

Most of the species are common to the King's Park and Langley Park Bores. Amongst them are *Hopkinsina* sp. (which according to Parr (personal communication) is possibly the first occurrence of this genus in Australia) an interesting species of *Globorotalia*, a species exhibiting unusual generic characters which may represent a new genus, and a puzzling species, possibly of the genus *Anomalina*.

It will be noted that some of the species recorded are unnamed and are suffixed by Roman numerals. This is a common practice for the purpose of local usage. Since the investigation was primarily of a stratigraphic nature no attempt was made to name them. Most of these species appear to be new and will be the subject of a later paper. Representative specimens of these and the named species are kept in the palaeontological collection of the Geology Department of the University of Western Australia.

COMPARISON OF THE KING'S PARK, LANGLEY PARK, AND BELMONT PARK BORES.

One of the objects of the investigation was to ascertain if a regular sequence of distinctive sections, based on foraminiferal evidence, could be recognised in the fossiliferous beds which the bores pierced.

As stated, only two of the bores yielded a vertical range of fossiliferous beds of reasonable thickness. The Belmont Park bore gave a seventy foot section from which a few species, too rare to be used for reliable correlation, were obtained.

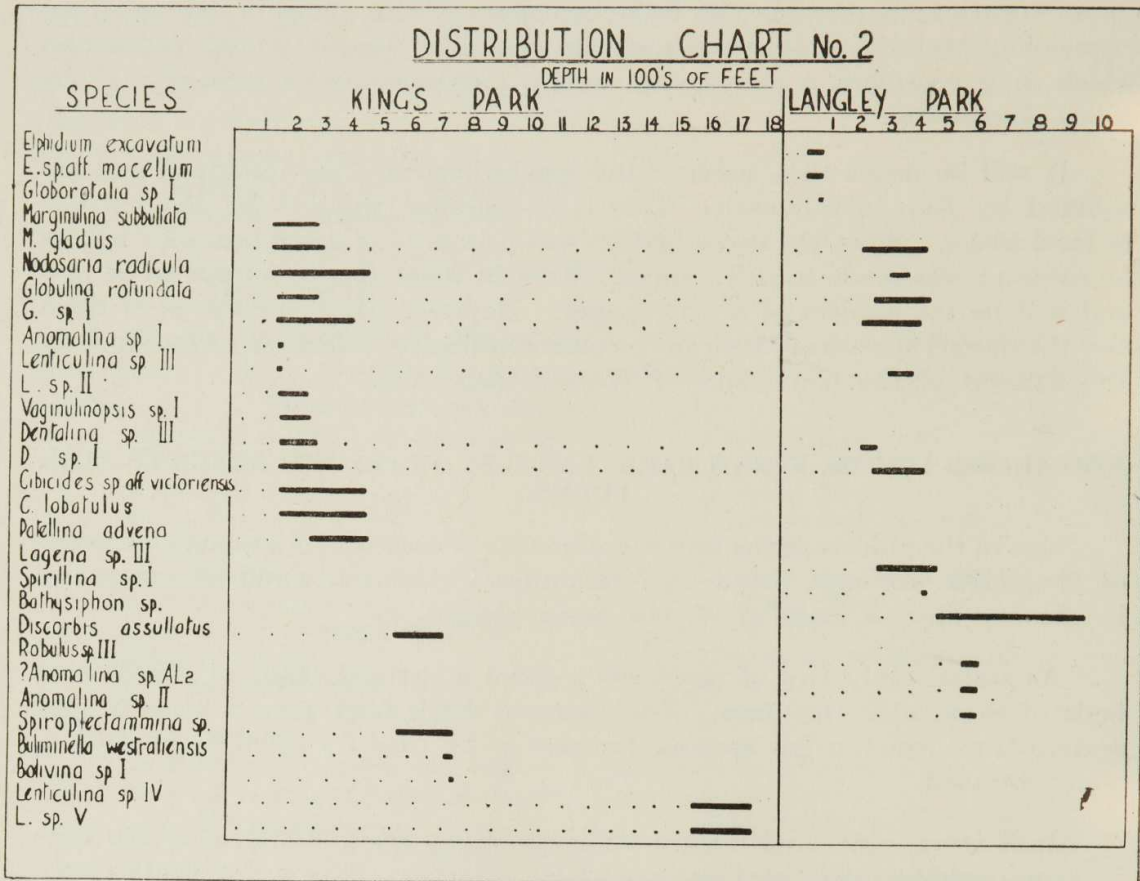
Indications, gathered from a study of Parr's work (1938), that the bore sections could be subdivided into groups (Quaternary, Eocene and Cretaceous), characterised by definite assemblages were fulfilled when a general distribution chart was drawn from a study of the foraminifera yielded from the three bores.

Analysis of this general distribution chart showed :

- (a) Those species which occurred throughout the sequence.
- (b) Those that occurred through the greater part of it.
- (c) Short-ranging species.
- (d) Species with changing frequency.
- (e) The distribution of accessory microfossils (ostracods, echinoid spines, minute corals and pelecypods, etc.).

Study of this chart revealed many species that were useless for subdividing the beds, *e.g.*, species that occurred through the sequence in practically the same frequency ; species occurring at rare intervals in varying frequency throughout the whole sequence ; species restricted to single samples. Rareness of a species was not regarded as a discouraging sign. Indeed many rare species are more useful than the more frequent ones. It must be noted that with the species of stratigraphic value are also found the many other "useless" species which tend to mask the presence of the fewer but more important forms, and hence the residues have to be examined with care.

Most of the species possessed little correlation value and so a second distribution chart was drawn up in which appear only those species thought to be of correlative value. Against each was plotted its frequency and occurrence, spaced to scale according to its stratigraphic range (see text fig. 3.)



Text fig. 3.

Distribution chart of those species considered to be of stratigraphic value, found in samples from the two bores which yielded foraminifera in any frequency.

Unfortunately some species that were of potential stratigraphic value, occurring frequently over a limited vertical range, were restricted to one bore and thus could not be used for correlation.

It was found that each bore could be divided roughly into bio-stratigraphic units, each characterised by:—

- (a) index species—restricted forms, and those in which the maximum frequency coincides with the unit.
- (b) Typical accessories whose first frequent occurrence marks the top of the unit.
- (c) Accessory species which need not be restricted to the unit but which exhibit a characteristic frequency through the unit.

The samples, having come from percussion bores, and the chances of contamination being rather serious, only the first frequent appearance of the species (*i.e.*, in descending order in the section) could be used with certainty to define stratigraphic horizons. In some instances a species would occur frequently over a small vertical range and then some hundreds of feet lower, an isolated rare instance would be found. It was thought justifiable in such instances to more or less disregard the isolated rare occurrence.

Ecological questions did not enter very much into the problem of correlation, although what *is* known about the structure of the beds, their lenticular discontinuous nature, would suggest that in large-scale correlation in the future the ecological significance of the faunas discovered will have to be seriously considered.

From a study of this second distribution chart (text fig. 3) it is evident that the King's Park Bore can be subdivided into five bio-stratigraphic units:—

- (1) A surface layer of Recent and Pleistocene coastal limestone, with very rare Recent and Pleistocene foraminifera, followed by unfossiliferous sand, clays, and bands of limestone, with a pebble conglomerate at 83 feet below the surface.
- (2) Between 84 and 300 feet (Eocene)—characterised by *Anomalina* sp. I, *Lenticulina* sp. III, *Marginulina subbullata*, *Marginulina gladius*, *Globulina rotundata*, *Lenticulina* sp. II, *Vaginulinopsis* sp. I, *Dentalina* sp. III.
- (3) Between 300 and 450 feet (Eocene)—characterised by *Patellina advena*, and overlapped between 100 and 450 feet, by *Globulina* sp. I, *Nodosaria radricula*, *Cibicides lobatulus*.
- (4) Between 500 and 780 feet (Eocene)—by *Discorbis assulatus*, *Spiroplectammia* sp. I, *Buliminella westraliensis* (728–55 feet).
- (5) Between 1,558 and 1,770 feet. This section produced only three species. *Lenticulina* sp. IV, *Lenticulina* sp. V, and *Dentalina* sp. aff. *colei*. It may be of Cretaceous age. (Note.—Lower Cretaceous foraminifera were found in the Leederville and Zoological Gardens Bores between 1,680–1,750 feet and 1,650–1,746 feet respectively.)

The Langley Park Bore can be similarly subdivided, but not so completely as the King's Park Bore, as follows:—

- (1) From 0 to 70 feet strata containing Pleistocene foraminifera—*Elphidium* sp. aff. *macellum*, *E. excavatum*, *Strebleus beccarii*, also an unidentified *Globorotaliid*.

This is followed by 130 feet of unfossiliferous sands and clays.

- (2) Between 200 and 450 feet—characterised by *Dentalina* sp. III, *Globulina* sp. I, *Marginulina gladius*, *Dentalina* sp. I, *Globulina rotundata*, *Lagena* sp. III, *Nodosaria radricula*, *Lenticulina* sp. III, and the lower by *Spirillina* sp. I.
- (3) Between 660 and 603 feet—indicated by the presence of *Anomalina* sp. II, *Robulus* sp. III, and ? *Anomalina* sp. AL₂.
- (4) From 470 to 951 feet characterised by *Bathysiphon* sp. in fair frequency.

The subdivision of the bores rests on the sum of species with comparatively short but overlapping ranges, rather than on restricted, disconnected, "characteristic" species. Unfortunately in both bores, between the third and fourth section in the King's Park, and second and third sections in the Langley Park Bore, there are no species which overlap from one to the other. In the Langley Park Bore, however, *Lagena acuticosta* shows a restricted increase in occurrence, between 450 and 555 feet.

It is immediately noticeable that species which are characteristic of a particular biostratigraphic unit in the King's Park Bore have much longer ranges or possess no stratigraphical value in the Langley Park Bore. Thus a biostratigraphic unit of the King's Park Bore is distinguished by the restricted occurrence of certain species which do not serve any such distinguishing purpose in the supposedly equivalent unit in the Langley Park Bore, and vice versa.

Since only two of the bores provided faunal data no explanation is offered to account for this fact. For the same reason it is not suggested that this would have been the case if a much larger number of bores had been studied. It suggests, however, that the Eocene beds may prove incapable of fine subdivision.

It is striking to notice the manner in which a high proportion of the species suddenly flash into prominence in both bores, *i.e.*, in the first fossiliferous samples after the surface material of Recent and Pleistocene age. This horizon, the top of the Upper Eocene, is at approximately 84 feet in the King's Park Bore, and 208 feet in the Langley Park Bore.

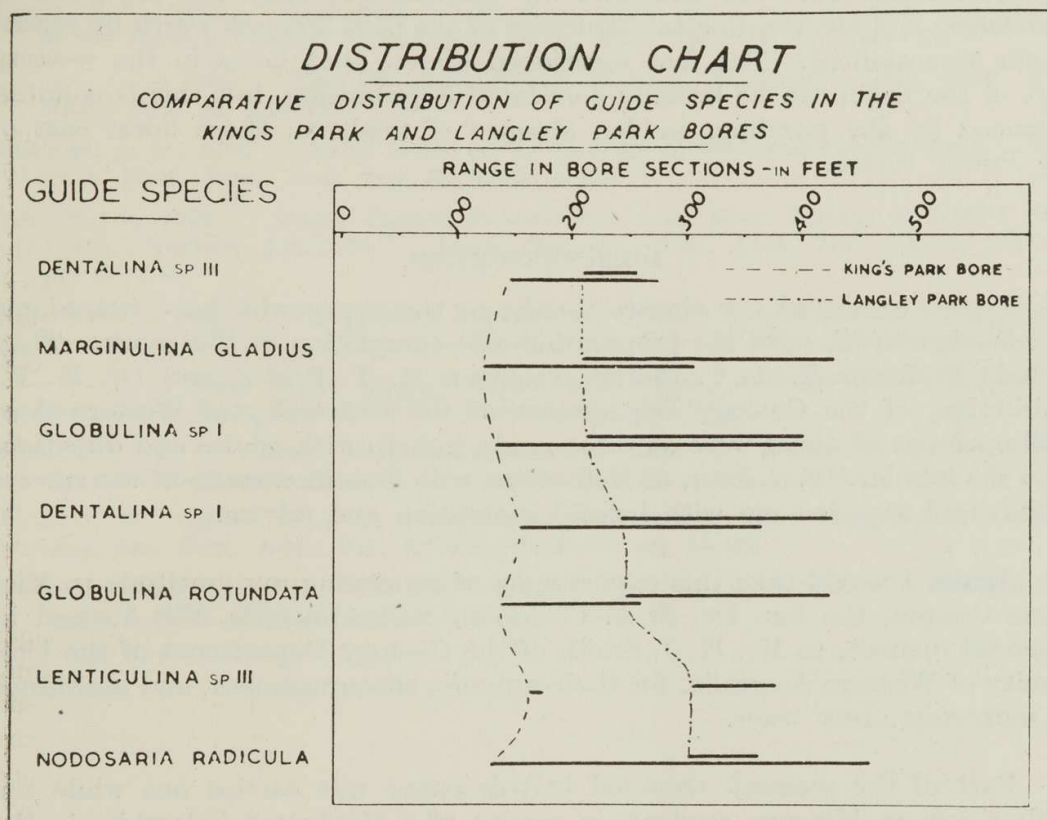
Only seven of the species of stratigraphic value are found common to both bores, which makes comparison of the two sections rather unsatisfactory. Probably many of the characteristic species peculiar to one bore could be found in the other, if searched for with extreme care. But the very necessity of a prolonged and careful search reduces their stratigraphic value.

A comparison chart (text fig. 4) was drawn showing the vertical ranges of these seven species in both bores. It can be seen that the lines joining the first frequent occurrences of the species are sub-parallel, and the mean vertical range between these lines is approximately 120 feet—the same figure as the difference in depth below the surface of the respective horizons which yield the first samples containing Eocene forms, namely, 84 feet in the King's Park Bore and 208 feet in the Langley Park Bore.

As the thickness of strata of Upper Eocene age is about the same in both bores, 770 feet in the Langley Park and 700 feet in the King's Park Bore, it would seem then that fossiliferous sections in the Langley Park Bore corresponding to those in the King's Park lie at a greater depth in the Langley Park Bore—approximately 120 feet deeper. This may indicate either a regional dip to the east for the fossiliferous strata, or the presence of a fault between the two sections. Further investigation of many more sections in the area is needed to confirm or refute this suggestion.

The Belmont Park Bore yielded 70 feet of fossiliferous material—between 830 and 900 feet, with an isolated sample at 530 feet. The foraminifera are rare and badly preserved, numbering only 17 species. It is impossible to correlate this short section with the other bores. For the most part it penetrated lithologically similar beds to the Power House Bore, about three miles to the west. It seems strange to find one bore with a comparatively abundant fauna over a vertical distance of 770 feet, and another only a mile away, completely barren of fossils and differing greatly in the lithology of the beds passed through. Thus the Langley Park Bore is fossiliferous, particularly between 208 and 975 feet, and then passes through unfossiliferous very sandy mudstone for nearly 600 feet. On the other hand, the Power House Bore only one and one-eighth miles to the N.N.E. passes through pyritic and carbonaceous sandy mudstones for its entire depth of 1,200 feet, and is completely unfossiliferous. These differences suggest that the sediments of the

Power House Bore were laid down in an area not directly connected with the sea, *i.e.*, they are of lagoonal or barred basin facies whereas the sediments of the Langley Park Bore are in part of true marine origin and in part of possibly lagoonal origin.



Text fig. 4.

Species of stratigraphic value common to the King's Park and Langley Park Bores. Arranged in order of first appearance in the Langley Park Bore.

From the analysis of material from these bores and examination of drillers' logs of bores throughout the whole area it seems that fossiliferous strata will be found at depths less than about 2,000 feet only to the west of a line trending approximately north-south through the Power House Bore.

The lithology of the strata through which the bores pass is of little help in correlation. It is interesting, nevertheless, to note the manner in which the foram-bearing shales and mudstones gradually increase in sand content from the west (the King's Park Bore) to the east (the Belmont Park Bore), followed then by unfossiliferous freshwater strata still further to the east, which may indicate a gradual approach to shore-line conditions.

CONCLUSIONS.

Although only two of the five bores examined yielded foraminifera over a vertical range exceeding 100 feet certain general conclusions and indications for future work can be drawn from this study. The King's Park, Langley Park, and Belmont Park Bores pass through strata with similar faunas to

those previously described by Parr (1938) as Upper Eocene* and the foraminifera may be used for correlating these strata. The lithology of the bores was of little use in correlation. The study has emphasised the need for the proper collection of samples from future bores.

Insufficient data are available for estimating closely the prospects of correlating and ascertaining the structure of the beds beneath Perth by means of the foraminifera. The fact mentioned above, that bores in the western part of the basin can be broadly correlated is promising, but this is counter-balanced by the puzzling, sudden absence of fossils in those bores east of the Power House.

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* Further evidence as regards the age of this fauna has recently come to hand. Miss I. Crespin, Commonwealth Palaeontologist, has kindly drawn the attention of the writer to a paper by F. Brotzen (Sveriges Geologiska Undersökning, Ser. C. No. 493, Arsbok 42, No. 2, 1948), in which a closely similar fauna from the Paleocene of Sweden is described. Brotzen has indicated the close relationship between this in turn, and the foraminiferal fauna of the Midway Group of Alabama, upon which the late Mr. W. J. Parr had largely based his original correlation. It is probable then that at least part of the fauna of the Perth basin hitherto assigned to the Upper Eocene, is of Paleocene age.

BIBLIOGRAPHY.

- Clarke, E. de C., Prider, R. T., and Teichert, C., 1944. "Elements of Geology" (University of W.A. Text Books Board).
- Forman, F. G., 1933. "Final Report on the Correlation of the Artesian Bores in the Metropolitan Area, Perth." *Geol. Surv. West. Aust., Ann. Rep. for 1932*, p. 9.
- Jutson, J. T., 1912. "Geological and Physiographical Notes on a Traverse over Portion of the Darling Plateau." *Geol. Surv. West. Aust., Bull. 48*, pp. 138-173.
- 1934. "The Physiography of Western Australia." *Geol. Surv. West. Aust., Bull. 95*, 2nd Ed.
- Maitland, A. G., 1902. "Some Notes on the Geology of the Swan Coastal Plain." *Geol. Surv. West. Aust., Ann. Rep. for 1902*, p. 21.
- Parr, W. J., 1938. "Upper Eocene Foraminifera from Deep Borings in King's Park, Perth, Western Australia." *Journ. Roy. Soc. West. Aust., Vol. XXIV.*, 1937-38, pp. 69-101.
- Prider, R. T., 1941. "The Contact Between the Granitic Rocks and the Cardup Series at Armadale." *Journ. Roy. Soc. West. Aust., Vol. XXVII.*, 1940-41, pp. 27-55.
- 1948. "The Geology of the Darling Scarp at Ridge Hill." *Journ. Roy. Soc. West. Aust., Vol. XXXII.*, 1945-46, pp. 105-129.
- Saint-Smith, E. C., 1912. "A Geologic Reconnaissance of a Portion of the South-West Division of Western Australia." *Geol. Surv. West. Aust., Bull. 44*.
- Wells, J. W., 1942. "Note on Fossil Corals from Langley Park Bore, Perth." *Journ. Roy. Soc. West. Aust., Vol. XXVII.*, 1940-41, pp. 95-96.
- Woolnough, W. G., 1918. "The Physiographic Significance of Laterite in Western Australia." *Geol. Mag., dec. VI., Vol. V.*, p. 385-93.